12.

AN EXPERIMENTAL INQUIRY

INTO

THE PHENOMENA

OF

SUSPENDED ANIMAL LIFE,

FROM

DROWNING, HANGING,

AND

THE ACTION OF NOXIOUS AIRS;

TOGETHER

WITH THE MOST CERTAIN AND EXPEDITIOUS MODE OF RECOVERING ANIMALS IN THAT STATE.

BY JOHN OSWALD,

OF COLLETON, SOUTH-CAROLINA;

HONORARY MEMBER OF THE PHILADELPHIA MEDICAL AND CHEMICAL SOCIETIES.

"Lateat Scintillula Forsan."

PHILADELPHIA:

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1802.

AN INAUGURAL DISSERTATION,

FOR

THE DEGREE

OF

DOCTOR OF MEDICINE;

SUBMITTED

TO THE EXAMINATION

OF THE

REVEREND JOHN EWING, S. S. T. P. PROVOST;

THE

TRUSTEES AND MEDICAL FACULTY

OF THE

UNIVERSITY OF PENNSYLVANIA,

ON THE 27th DAY OF MAY, 1802.

TO MATTHEW IRVINE,

PHYSICIAN OF CHARLESTON, SOUTH-CAROLINA.

MUCH RESPECTED SIR,

A MEDICAL honour, the approbation of a university, is considered as a just compensation to the student, for the progress and acquirements he has made in his profession. This honour, sir, I am now about to receive, as the fruits of a medical education, which, I am happy to say, was commenced and completed under your immediate care. To pass over, in silence, the many valuable instructions which I have received from you, both in a public and private way, together with the very many medical precepts I have imbibed from your communications, (to practice which, shall always be my desire,) would be sacrificing that gratitude which you so eminently claim from all your pupils.

Please to accept, then, sir, this dedication, as a small tribute of the respect I have for yourself, and for that eminence which you so justly enjoy in the republic of medicine. That your invaluable life may be continued, without interruption, till the infirmities of age render it no longer desirable, for the happiness of your worthy family, the great satisfaction of your friends and those who have the pleasure of your acquaintance, and, lastly, for the benefit of all mankind, is the ardent and sincere wish of

Your affectionate and

Grateful Pupil,

THE AUTHOR.

TO THE HUMANE INSTITUTIONS

OF

MY NATIVE COUNTRY.

GENTLEMEN OF THE HUMANE SOCIETIES,

PERMIT me thus publicly to express the high estimation in which I hold your philanthropic institutions, and the sentiments of esteem I have for you, individually, as fellow citizens. Your exertions, in the noble cause of humanity, have been extensive, and have been crowned with success. They are progressing daily throughout this vast continent, to the happy end for which your societies were founded. Your deeds will, in a future day, be read in the history of the western world, with admiration and applause: they will form a conspicuous æra, in the annals of our history, and serve as a powerful incentive to those who shall come after you, to engage in the same cause....TO DIMINISH THE NUMEROUS OUTLETS TO HUMAN LIFE! Already have you rescued from a premature grave, and recalled to life, by your timely exertions and perseverance, many unfortunate persons; perhaps, among these a kind parent, an affectionate husband, on whose industry depended the happiness, perhaps existence of whole families. Society will ever remain indebted to your efforts in this glorious cause. Your exertions have restored to her many valuable members*, and will, doubtless, restore many more. Citizens, as we are, of one of the most delightful, and happy countries in the world,

* The records of history, authorise us to report, that from 1767, to 1797, a space of thirty years, three thousand two hundred and twenty-nine persons have been restored to life, through the medium of these truly benevolent and invaluable institutions. This account must be very superficial, as it does not include the vast republic of France, and many other nations, throughout which, humane societies have been long since instituted. Here is then, from this deficient estimation, upwards of one hundred and seven persons annually restored to life, throughout different parts of the world! a pleasing reflection to the eye of humanity.

we should, in unity, love and promote each others happiness: we should all unite in the same godlike cause, and contribute, each of us our portion, to the cultivation of *humanity*. History will never have it in her power, to reproach the American character with illiberality in the cause of humanity. For the same principle which gave origin to these exalted institutions in the old world, has never been, nor ever will be, foreign to the American breast; actuated by the same glorious motive, and a great desire, to cultivate every thing which tends to the ultimate happiness of their fellow men. Charitable and humane institutions* are now, and have been, for some time past, in rapid progression throughout this happy continent. In respect to that part of it which relates to medicine, it has received the indefatigable exertions of many great characters; but there remains yet much to be done; for notwithstanding men of great talents, have been deeply engaged in investigating its intricacies, and have shed much light on the subject, there is still, and will be for centuries to come, a vast field for important investigation. That our joint efforts, in this cause, may be continued as we have begun, without intermission, to the end of time, and that they may be crowned with success is my ardent desire. If these, my feeble efforts, which I have taken the liberty to dedicate to you, should contribute, in the least, to promote this much-desired end, it will afford me a considerable share of happiness. That you may individually in life, receive the just reward of your unrivalled exertions in the cause of humanity, and that a large portion of happiness, which you so highly merit, may always attend you, is the most sincere, and the warmest wish of

Your friend and
Fellow citizen,
THE AUTHOR.

* Although America, at present, bears, in point of number, but a small proportion in the above account, when we take into consideration several circumstances, such as the great disproportion of inhabitants, the recent establishment of the different societies, &c. &c. it will appear that she is not far behind, and at any rate, the utility of her socities is certainly as extensive as, those of Europe.

TO PAUL WALTER, Esq.

OF COLLETON, SOUTH-CAROLINA.

WORTHY SIR,

WITH a heart flowing with gratitude, a tribute which no one claims from me in a more eminent degree than yourself, and that not only for your parental guardianship, since the death of my long lost parents, from which period, to that of a few years past, I have had the happiness to reside with you, and to enjoy, to the utmost, your immediate care and friendly guidance; but, sir, for the continuance of that friendship, ever since my leaving your happy and hospitable mansion; for which I am doubly indebted to you, (and to merit which, shall always be my greatest desire) and in return for which I now publicly offer for your acceptance, my most sincere acknowledgments. Be assured, sir, that the very many friendly obligations which you have heaped upon me, shall never be erazed from my memory. No, they shall be cherished in my recollection, and, to the end of my life, awaken the liveliest sensations of esteem for you. With my best wishes for your future happiness and prosperity in life, I subscribe myself

Your sincere friend and
Fellow-citizen,
THE AUTHOR.

PROTOLOGY so frequently appears in essays of this kind, as excuses to the world for juvenile performances, that it is only necessary for me to say, that from the man of talents, candour, and liberality, I anticipate that lenity which is usually bestowed on the productions of youth, and its consequent inexperience; when the extent of the subsequent sheets are viewed in a true light, the importance and extremely difficult nature of the subject, together with the short time allowed by the laws of the university for preparing them, they will at least claim the indulgence of those, who have been engaged in works of the kind; and the generous mind will not hesitate to attribute their errors to the immediate sources of their origin.

INTRODUCTION.

SINCE the term SUSPENDED LIFE has been objected to, as not applicable to this subject, it is necessary that I should inform the reader of the sense in which I use it. I mean by suspended life, that state of the animal body, in which motion is not perceptible, though the capacity for it still exists; which may again be roused into action, by the application of active powers, either internally or externally, or by both. This susceptibility to the impression of stimulus, is what constitutes the peculiar and only difference between life and death, or animated and inanimate matter; and on the presence of which entirely depends the recovery of animals labouring under asphyxia, from whatever cause.

It is not my duty here to enter into a full discussion, relative to the propriety or impropriety of the term suspended animation, which has been objected to by two late and very ingenious authors*, in consequence of a belief, that there was no intermediate state between life and death. Now the word intermediate is certainly used here to imply a particular degree or grade of life, a middle state, &c. which these gentlemen, from their writings, are not disposed to grant. The very late discoveries made in the important phenomena of animal life, prove this assertion to be utterly void of foundation; for, according to that idea of life, an animal must either enjoy it in its most perfect state†, or immediately become a mass of dead matter....there being no inferior grades of life. Now this hypothesis, at first sight, will certainly appear, to the mind of every unbiassed reader, as being completely erroneous. That animals enjoy life in different degrees, accordingly as they

* See Dr. Goodwyn and Mr. Coleman.

† Perfect life I conceive to be synonimous with perfect health.

are influenced by foreign agents, is fully evinced, when we take a view of them in different parts of the world;* and again it is as obvious, that they possess it at different seasons of the year, in the same countries and places, in various degrees, from a perfect state, down to one in which it is not perceptible, as is evinced in complete hybernation, in which state they possess life in the least degree possible. Now, if there was no intermediate state between life and death, and if there could be no suspension of life, without exhaustion, I would ask the gentlemen, or their advocates, for a solution of the fact, that animals are frequently recovered from this state of torpidity, as the inferences drawn from this state are applicable to a suspension of life from any other cause. By *suspension*, no one of common understanding, who is not biassed by pre-conceived ideas, could suppose I meant to imply an irreparable exhaustion of life, the only definition which these gentlemen seem to suppose can be given of it.

I have already carried this disquisition too far. It is my wish to avoid prolixity, as much as possible. At the time I determined on this subject, in compliance with an indispensable rule of this university, I intended to have extended it no farther than to the investigation of suspended life, from submersion in water; but observing the immediate connection betwen suspension of life from drowning, and that produced by the noxious gases, I was induced to take a cursory view of this last subject also; for although accidents do not as frequently occur from this source as from submersion, it is still not unfrequently a cause of human misery, and merits, in an equal degree, the attention of the physician.

The reader will please to observe, that many of the experiments inserted in this essay, have long since been made, by very ingenious and accurate experimentalists, but some of whom were, at the time, labouring under the powerful influence of a favourite theory; in consequence of which, to establish their respective doctrines, their experiments were performed either in a partial or incorrect manner, and their conclusions drawn so replete with prejudices, as to excite

* Vide Rush on Animal Life, lecture 3.

scepticism in the impartial reader. In consequence of which, I was induced to believe, after viewing the controversy on both sides, that error was as much to be attributed to the one as the other; and, to satisfy myself, I was led to repeat many of them, with the view of ascertaining, as far as I was capable, the truth of their results, and correctness of their inductions. One of these accurate experimenters*, like the philosopher, sensible that error is not foreign to human nature, in every capacity, earnestly requests (with a degree of diffidence and philosophy, which will ever reflect much honour on him) that his experiments should be repeated before they were received as facts and their errors adopted. Let me repeat, in justice to this candid and truly ingenious author, that he had far less occasion to make this request, than many others....many who have much greater inducements to be candid.

Fully convinced of the extreme fallacy of experiment, from the results of which so many unhappy mistakes have originated, I performed them with as much deliberation and accuracy as I possibly could. Not trusting to my own senses for observation, I solicited the attendance of several of my friends, who I knew were possessed of the spirit and talent for close investigation, in an eminent degree, whose names I shall take the liberty to mention. To that accurate anatomist, my ingenious friend, Dr. Jacobs, I am much indebted for his extensive assistance throughout my dissections; and also to my friends Dr. Roebuck, Mr. Foissin my fellow student, and Mr. Grimes, who afforded me occasionally their assistance.

I have now to offer an apology to the sensible reader, for the scenes of horrible cruelty and torture into which I am about to lead him;....they are truly poignant to the sensibility of the human heart. Do not suppose that the author himself escaped this poignancy! No; at first, he felt it as keenly as you will; but viewing the cause of it in its genuine light, in which he saw the welfare of his fellow men involved in a considerable degree, it assured him, that he had a just claim to the forgiveness of the injured, when it was not simply curiosity which acted as the incentive.

* Dr. Goodwyn. See Introduction, page xvi.

SINCE no one, from the prince to the peasant, can, at all times, be secure from those dreadful disasters, which suddenly suspend vital action; and since medical practitioners themselves are not exempt, it surely becomes them to use every exertion to *improve* the art of *restoring animation.* May each progressive step in this interesting path of science, tend to that great object! and may every laudable attempt, undertaken with that benevolent view, enable us, with more certainty, to preserve life, and to diminish the sum of human infelicity!

DR. FOTHERGILL.

AN EXPERIMENTAL INQUIRY

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SUSPENDED ANIMAL LIFE.

EXPERIMENT I.

I SUBMERSED a grown dog, in common pump water, not allowing him to respire atmospheric air during the process; he struggled violently for one minute and fifty seconds, attempting frequently to rise to the surface: During his struggles he made several efforts to inspire, emitting at the same time, from his lungs, a large quantity of air. He was taken out dead in three minutes and five seconds. On dissection, in the presence of my fellow-graduate, Mr. Dorsey, who assisted me, the lungs were found of a dark colour, and very little collapsed, containing two and a half ounce measures, of a yellowish frothy fluid, which appeared to be water mixed with the natural mucus of the lungs. No susceptibility remained in the heart, both sides of which were found to contain black blood, the right side having most in quantity; the blood vessels of the brain, particularly the sinuses, were full of extremely dark coloured blood, but were not turgid. No extravasation was observed, between its membranes, nor any effusion in the cavity of the ventricles.

Another dog, of the same size, was treated in a similar manner: his pulse, in fifteen seconds after he was plunged under water, became more frequent and less full than na-

tural; in thirty seconds less frequent and more full; in sixty the same, still struggling very hard; in one minute and twenty seconds, it became slow, and the pulsations full though not very strong: in one minute and forty seconds the same; in two minutes, the pulsations were very few, and more feeble; in two minutes and twenty seconds, not more than twenty pulsations in a minute and very feeble; and in two minutes and fifty-five seconds, he died. Before he was taken out of the water, and while below its surface, a ligature was applied round the trachea, to prevent any communication between the external air, and the air cells of the lungs, after which the thorax was opened and the lungs removed; the ligature was now taken off, and the air contained in its cells forced out by pressure, and received into a four ounce phial, inverted over water in the pneumatic-tub; which it somewhat more than filled. The air was now tested with a taper, which it extinguished repeatedly. On dissection, the internal appearances were nearly the same as occurred in the preceding case.

EXPERIMENT II.

A very large cat was plunged under water, and confined there. Her efforts to relieve herself, during the process, were violent and distressing; she was taken out at the expiration of three minutes, perfectly dead to appearance; but on opening the cavity of the thorax, her heart was made to contract violently for several minutes; the motion appeared to be equal in both sides. The blood in the right side was very black, and also in the left, the ventricle of which was found to be half full; the lungs were much collapsed, but I obtained from them, two and a half cubic inches of air, mixed with water and a yellow froth; the air was then separated, and sent up through a column of lime water contained in the eudiometer and inverted in the pneumatic tub. On agitating the air with the water, a considerable absorption took place, and the water became very turbid. The remaining small portion of air was tested by nitrous gas in the eudiometer, and found to be azotic gas

with fixed air. The brain was found in a natural state, with its sinuses full of black blood. About half a pint of water was found in the stomach. The irritability* of the intestines was not perceptible, though that of both sides of the heart continued a considerable time. The mesenteric vessels were full of black blood, in every instance.

EXPERIMENT III.

A full grown bull dog was submersed, by means of a halter put round his neck, and one end of it carried through a pulley, fixed to the bottom of a very large trough filled with water; the animal struggled, with astonishing force, for a considerable time. Having previously fixed a glass bell, to receive the gas he would evolve from his lungs, during the process, by evacuating the air, and inverted it over the water in the same trough, immediately above the animal's head: I prepared two of them, to enable me to procure the gas in separate portions. The first bubbles of air which rose to the surface I allowed to escape, being, perhaps, the air contained in his mouth and nostrils. In five seconds after his head was under water, and the bubbles of air were rising to the surface, I applied my glass vessel, and collected every inch. I obtained in this manner fifty cubic inches of air, twenty-five in each vessel. On being tested by the eudiometer, no difference could be observed. Two cubic inches of air, from each of the portions, were thrown together into a wide mouthed phial, which put out a taper repeatedly when plunged into it; into the remaining forty-six inches, contained under a glass bell inverted over water, was plunged a small kitten, which died in eight minutes and ten seconds, and on dissection exhibited appearances similar to those which were exhibited by the submersed animals.

This large animal appeared to be very tenacious of life: struggling to the last, with much violence. He died suddenly in four minutes and fifteen seconds, the gas had

* Irritability and susceptibility will be used, indiscriminately, as synonimous, throughout this essay.

ceased to come over in two minutes after he was plunged under water. The pulse of this animal, with some little variation in degree, was very similar to experiment the first. On dissection, the appearances of the blood were the same as related in the other experiments. The irritability of the heart was not perceptible. The mercury in Fahrenheit's thermometer standing at sixty-six, when plunged into the right ventricle it rose to ninety-eight: in this situation it was kept for thirty seconds, but rose no higher, when it was plunged into the left auricle and ventricle and fell to ninety-seven: the temperature of the animal was ninety-eight before he was submersed. This experiment was repeated at three different times on animals of the same kind of various sizes. The gas evolved from the lungs during submersion, was different in quantity, in proportion to the difference of size; but I never procured less than two and a half cubic inches, in which I never could detect the least portion of oxygen gas through the medium of nitrous air, in the eudiometer. Lime was frequently precipitated from its solution in water, in the form of carbonate of lime, when this gas was sent up through it.

EXPERIMENT IV.

I inverted my glass bell, filled with common pump water, over the pneumatic tub, in which I then placed two half grown pups, and one kitten. I could now distinctly observe the effects of submersion. The animals appeared to labour under great distress, (which evidently seemed to be about the region of the thorax,) making frequent efforts to inspire without the power of effecting it. Whenever the animals attempted to inspire, water was observed to pass down into the pharynx, being indicated externally, by the motion excited in that part, which was exactly similar to that caused by pouring large quantities of fluid down their throats. They emitted air from their lungs for several seconds while under water. In one minute and forty seconds, the two pups became much exhausted, and death was indicated in a short time, by their feeble attempts to

inspire: the tongue and gums, which were before of a red colour, now assumed a dark leaden hue; there was great debility in the extremities; and a considerable dilatation of the pupils of the eye, but which would still contract, in some degree, when a vivid light was applied. Their eyes somewhat protruded, and more transparent than natural. The two pups died in two minutes and fifty seconds, and the kitten in three minutes. They were dissected, and the results were the same as contained in the other experiments.

EXPERIMENT V.

A very large dog was plunged under water, at twenty minutes after four o'clock; and in consequence of his superior strength and very severe struggling, he attained the surface several times, during submersion, making at the same time, a deep inspiration, which was repeated, whenever he rose above the surface. The inspirations were followed by several expirations while confined below it. The effect of every single inspiration, was that of decidedly invigorating his whole frame, which was evinced by a considerable increase of force in his efforts to escape; the pulse during his severe struggling was quick and full, which lasted for five minutes, when it became slower, but still as full. Towards his death it became very slow, beating but twenty strokes in a minute; the pulsations indicating the heart to be engorged with blood. The animal died in eight minutes and thirty seconds. He was then taken out and dissected, and exhibited the following appearances.....The blood in the right side of the heart, was of a dark colour, that in the pulmonary veins and left auricle somewhat lighter. The heat of the left side of the heart, when the thermometer was plunged into its auricle and ventricle ninety-nine of Fahrenheit, that of the right side the same. The temperature of this animal before he was submersed was at ninety-nine. The sinuses of the brain were full of black blood, but were not turgid.

EXPERIMENT VI.

TO ASCERTAIN HOW FAR THE INFLUENCE OF STIMULUS, ACTING UPON THE IRRITABILITY OF THE ANIMAL BODY, FACILITATES DEATH, THE FOLLOWING EXPERIMENTS WERE MADE.

I procured six pups of the same litter, being about three weeks old. Into water, heated to the temperature of one hundred and forty degrees of Fahrenheit's thermometer, I plunged two of them. The little animals struggled severely for a short time; the pulse was much increased in frequency, and somewhat stronger than natural. They made several efforts to inspire, and one of them died in one minute and forty seconds, the other in one minute and fifty seconds. On dissection, the blood in both sides of the heart was very black, and the irritability not perceptible in either. The blood appeared somewhat dissolved.

Into common pump water (the temperature of which was sixty degrees by Fahrenheit's thermometer) two of the same litter of pups were plunged; the temperature of these animals was at ninety. They both struggled hard for two minutes and twenty seconds, at which time they began to appear very weak: pulse slow and feeble, their efforts to inspire much diminished in frequency and strength, and weakness in the extremities very great. The first died in three minutes, and the second in three minutes and five seconds. On dissection, the irritability of the heart still existed, and continued for several minutes. Other remarks were the same, when we except the dissolved appearance of the blood.

To discover if any peculiarity of constitution existed in their systems, which may have rendered them more or less tenacious of life, which is different, in some degree, in almost any two animals, the remaining two were submersed in the same water, in which the others were drowned, the temperature of which was still at sixty degrees. The first died in three minutes, and the other in

three minutes and twenty seconds. Here we observe, that the difference of susceptibility in each of the pups was very inconsiderable, much less than perhaps would have occurred again, under the same circumstances.

OF THE COMMON EFFECTS OF SUBMERSION, VISIBLE EXTERNALLY, TAKEN FROM THE PRECEDING EXPERIMENT.

An animal, as soon as he is plunged under water, as if conscious of what will happen, becomes in a manner furious in his struggles, and attempts, by violent efforts, to escape. Frequent attempts are now made to inspire, without the power of effecting it, which are followed by expirations of air from his lungs, which rise to the surface. The greatest distress attending, is evidently about the region of the thorax, which becomes much (in consequence of the air expelled) diminished in capacity. The pulse of the animal, for the first twenty or thirty seconds, is frequent and weak, at least more so than natural; but a very considerable change is produced in it, from one to two and a half minutes after submersion, becoming slower and more full, indicating engorgement about the heart, and, in some instances, as slow as from fifteen to twenty strokes in a minute, from which it gradually decreases, till it becomes suspended altogether. During the efforts to inspire, the animal swallows a considerable portion of water, which is evinced, during the process, by the motion excited in that part; his pupils are much dilated, and eyes somewhat protruded, which are more glossy than usual. About the period that death occurs, the tongue and gums, which were before of a healthy red colour, are now changed into a leaden blue, and sometimes a very dark colour is observed. The animal is now taken out apparently dead, in from one to four minutes.

These results do not differ essentially from those given by Dr. Goodwyn, in any point, except that of the pulse. The doctor is certainly correct in saying, that the pulse is

weak and frequent, which is actually the truth, but which observation will extend no farther than to the first twenty or thirty seconds after the animal has been plunged under water, and which I take to be the effect of fear, together with the sudden change of temperature. Had the doctor extended his observation farther, throughout the process of submersion, it is probable he would have been convinced of his error.

CONCLUSIONS FROM THE RESULT OF THE PRECEDING EXPERIMENTS, DISCOVERED TO US BY DISSECTION.

1. We observe, that, either from a peculiarity of constitution, or some other circumstances, different animals, of the same genus, are more or less tenacious of life; but that, in submersion, they are in common taken out apparently dead, in from one and a half to three or four minutes (I say apparently dead, for they are frequently recovered, by the application of proper means) after this period.

2. That the arterial blood has been completely deprived of its natural red colour, and, in every instance, is as black as veneas blood, throughout the whole body.

3. That the left auricle and ventricle of the heart are found about half full of the same coloured blood, and also the pulmonary artery, and veins leading to the left auricle.

4. That the right auricle and ventricle are found, in every instance, distended with extremely black blood, and also the two venæ carvæ leading to it.

5. That, on immediate dissection after submersion, the heat of the blood in the left side of the heart is equal to the temperature of that in the right, differing, in one or two instances, only in one degree, which small difference was sometimes in favour of the right, and as frequently inclined to the left. Having but one thermometer, the variation may, in a great measure, be attributed to the space of time which was lost, in applying it to both sides.

6. That whenever the heart retained its irritability, on dissection I never could discover any difference in degree,

between that existing in the left and that in the right side; neither could I discover that the one side retained, or parted with its irritability sooner than the other.

7. That the lungs are found of a dark colour, and in some instances very little collapsed; while in others about half so, but containing from one and a half to fifty cubic inches of air, which is in proportion to the various size of the animals.

8. That the air thus procured from the lungs, after death from drowning, on being minutely tested in the eudiometer, never, in any instance, yielded the least portion of oxygen gas, and proved highly fatal to animal life, as in the case of the kitten.*

9. We discover in the lungs after death, from one to two and a half to three ounce measures of a yellowish frothy kind of fluid, which is found to be water mixed with a small portion of the natural mucus of the lungs, from which we separate from one and a half to two and a half ounce measures of pure water, and discover in common from four to eight and sixteen ounces in the stomach.

10. That no turgescence, extravasation, or effusion occur in the vessels, or cavities of the brain, which although the former, in almost every instance, are found full of extremely black blood, are never moderately distended.

11. That we observe no difference of temperature in an animal on dissection, immediately after death from submersion, from that which existed before he was submersed.

12. That in consequence of respiration being cut off, the blood is deprived of the red colour, communicated to it by the oxygenous part of the air we take in at each inspiration.

13. That animals submersed in a high temperature, die† much sooner than those in a lower one, as in experiment the sixth, where the animal irritability was acted

* See Experiment 3.

† The result of an experiment of this nature, made by Dr. Crawford accords with this observation. Vide his work on Animal Heat.

upon by a force of stimulus, superior by eighty degrees, to those submersed in a medium standing at sixty.

14. That the irritability of the heart and muscular fibres was discovered, in many instances, to be so much exhausted as not to be indicated by the application of the most powerful stimulants.*

OBSERVATIONS ON THE SUPPOSED PROXIMATE CAUSE OF DEATH.

In ancient physiological researches, the immediate cause of death from drowning was attributed to a portion of water found in the lungs on dissection. That water does enter the cavity of those organs in the quantity of from two and an half to three ounce measures has been proved long since by experiment. We must now attempt to discover whether it enters during the efforts of the animal to inspire, or passes into it after death has taken place, in consequence of its gravity and the pressure of the external air. Both sides of the question have been ably supported, each having nearly an equal degree of plausibility attached to it. We observe, from our researches, that the quantity of water found in the lungs varies in proportion to the capacity of the parts; and again, its quantum is in a considerable degree influenced by the time the animals were allowed to remain under water. We must now, to satisfy ourselves, and dispel our doubts, have recourse to the only standard of truth in physiological investigations,....I mean accurate experiment.

EXPERIMENT 7.

Having filled a large earthen jar with a strong solution of the sulphate of iron, I submersed two large pups, not

* Such as the actual cautery, the stimulus of the Galvanic influence, which was derived from a chain of one hundred and fifteen tumblers, each containing a flat square piece of zinc and copper, connected together by brass wire.

permitting them, during their struggles, to rise above the surface. They both struggled severely for some time, making frequent efforts to inspire, and indicating externally convulsive action in the region of the stomach: they were taken out dead in three minutes, having previously applied ligatures to the trachea, with a view to prevent the escape of the solution from the lungs, if any should have entered. The animals were now dissected; the irritability of the heart was imperceptible, and its blood extremely black. The lungs were now removed from the thorax, the ligatures remaining round the trachea, and were put into two clean dry tumblers. Incisions were now made into several parts, through which a quantity of a greenish coloured fluid was pressed out, mixed with air and frothy matter, in the quantity of from two to two and an half ounce measures. From the proportion of matter which came from one of these animals were separated two ounce measures of water, to which I added the prussic acid, when a beautiful blue was formed, (the prussic acid uniting to the iron of the solution and forming Prussian blue.) On the portion obtained from the other pup I poured the alcohol of galls, which formed a good ink. Here we observe, that as much of this solution enters the lungs in drowning, as common water, and consequently it must be supposed to find its way into those organs with as much facility. Hence can be inferred no inaccuracy arising from its very styptic quality.

EXPERIMENT VIII.

A half-grown dog was plunged into the same solution, and confined in it for one minute and fifty seconds; at which time he became very feeble, but still making efforts to inspire, in two minutes after he was removed from the solution, he became more strong, and was able to walk about, he made several efforts to vomit, in one of which he brought up a small portion of a slimy fluid, to which the prussic acid was added, detecting it to be the solution of iron: there was also a considerable degree of irritation

about the larynx, in ten minutes his trachea, was laid bare, and a ligature applied, when he died in one minute and ten seconds. The lungs were now dissected from the body, and cut up into small portions, to each of which the prussic acid and alcohol of galls were added, in the presence of two of my friends, and no change of colour was produced. In the stomach it was detected to the quantity of ten ounce measures.

EXPERIMENT IX.

Having procured four pups of the same litter, about four weeks old, and well grown, I submersed two of them in the same solution, taking care not to permit their rising to the surface of the fluid. After repeated efforts to inspire, and much struggling, they were both taken out in one minute and forty seconds, at which time they were still lively, both of them making several efforts to vomit without effecting it, they were allowed to remain at liberty for twenty minutes, at which time ligatures were applied to the trachea, and suffocation produced, after which the cavity of the thorax was laid open, and the lungs taken out, and dissected, to which were added the different tests, but without the effect of producing any change of colour, the stomach was now carefully examined in which was found three and a half ounce measures in one of the animals, and in that of the other four ounces. The canal of the trachea was particularly examined by the different tests, in which none of the solution could be discovered. The other two pups were treated in the same manner, and with the same results. Three small kittens were treated in a similar manner, with the same effects, differing only in degree.

EXPERIMENT X.

Two kittens of three weeks old, were plunged into a strong solution of sulphate of copper, and were allowed to remain in it for the space of two minutes, at which time

they were taken out, in a very languid state, but immediately began to respire, and in a few minutes became very lively; there was great inclination to vomit, with the effect of throwing up some of the solution, which was of a blue colour. In five minutes after they were taken out, ligatures were applied to the trachea and œsophagus, to prevent the escape of the solution, the animals were now dissected, and the lungs examined, in which I could discover none of the solution, the stomach of each of them was found to contain ten drachms of a bluish coloured fluid, which was received into a wine glass, and a polished key placed in it, which in a few minutes became covered with a precipitation of copper from the solution.

The inferences from the above experiments are obvious. They prove, in a satisfactory manner, that the fluid generally found in the cavity of the lungs, after death, from drowning, does not enter those organs, during the life of the animal.

We must now, to draw our conclusion, observe the effects of submersion, after the extinction of life.

EXPERIMENT XI.

The trachea of two large pups, were laid bare and ligatures applied; they both died in one minute and fifty seconds; the ligatures were now removed, and in five minutes after, they were plunged into a solution of the sulphate of iron, (having previously observed that the wind-pipe was perfectly clear, and not obstructed, as I have seen it by severe compression,) in which they were permitted to remain for the space of two minutes, they were then taken out and dissected, in the presence of Mr. Dorsey; ligatures having been applied round the trachea, immediately on being taken out, to prevent the escape of the solution, if any should have entered. The lungs were now examined, and were found to contain three ounce measures of fluid, from which was separated a small portion of froth, and the natural mucus of the lungs, the prussic acid was now added to a part of the remaining portion, which struck a beautiful

blue with the iron of the solution; to another portion, the alcohol of galls was added, when a good ink was formed.

Three small kittens were treated in the same manner, and with the same results, varying only in degree, except in one, which singular circumstance, began to excite my doubts, and induced one to believe there was some inaccuracy existing, of the truth of which I was soon convinced, when I laid bare the whole extent of the wind pipe, where I found that part of the trachea to which the ligature had been applied, completely obstructed, in consequence of violent compression, which had so disorganised the part as to prevent it from regaining its natural elasticity.

From the severe test of experiment, we can now, in truth, assert, that water (or in fact any other fluid) in drowning does not enter the cavity of the lungs, during the efforts of the animal to inspire, but finds its way into those organs through the aperture of the glottis, after the exhaustion of the irritability of those parts, (in consequence of which they become considerably relaxed) through the medium of its gravity and the pressure of the external air*. We will now repeat the same experiments, on the same kind of animals, making use of a far more dense medium, the specific gravity of which, compared to water, is as 13,568 to 1,000.

EXPERIMENT XII.

I submersed two pups of eight weeks old each (one after the other) in an earthern jar filled with quicksilver, taking care to prevent their respiring atmospheric air during the process. The first struggled violently for one minute and forty seconds, making frequent attempts to inspire. In two minutes he became very feeble, which rapidly increased, and he died in three minutes. The

* Dr. Goodwyn, who made experiments similar to these, some time since, with ink, concluded that the fluid detected in the lungs, had entered during the efforts of the animal to inspire.

other died, in the same manner, in two minutes and fifty seconds. They were then dissected, and exhibited appearances the same as those drowned in water. In the air-cells of the lungs of the first were found three drachms of mercury mixed with a yellowish frothy kind of fluid, inclining to a brown colour. From the lungs of the last I procured six and a half drachms. Two other pups about half grown, were treated in the same manner, and, on dissection, the lungs of the first were found to contain five and a half drachms, and those of the second five drachms of mercury.

We here observe, that, notwithstanding the great difference of gravity between the two fluids (water and mercury) the proportion of the former found in the lungs after submersion to be four times equal to that of the latter. The inference to be drawn from this fact tends considerably to prove, that the mercury did not enter the lungs during the efforts of the animal to inspire. It cannot be denied that the impression of mercury is not more powerful or foreign than that of water on the windpipe and its appendages. Hence, if it had been taken in during the efforts to inspire, we ought certainly to find it on dissection equal in quantity to the water found in the lungs, which is not the case. We will now determine it by experiment.

EXPERIMENT XIII.

Two pups, of six weeks old, were plunged (at different times) into a large quantity of mercury, contained in an earthen jar, observing to confine them below its surface, during the process, with my hand. They were both confined in it for the space of one minute and fifty seconds: having made repeated efforts to inspire during the time of submersion, they were feeble when taken out, but began to respire, and were soon revived. They were then kept in a perpendicular position, with their heads upwards, for five minutes, at which time ligatures were applied round the trachea, and the animals suffocated. Both of them, immediately on being taken out

and placed in a perpendicular situation, discharged mercury per anum. The lungs were now examined, by putting them into a clean tumbler, filled with clear water, after which the ligatures were removed, and the lungs minutely divided by the fingers; after which the tumbler was examined, and not a single globule of mercury was found in it. About six drachms were detected in the stomach and bowels. Other appearances were the same as those observed in the preceding experiments.

From these researches we conclude, that this ponderous fluid does not enter the lungs during the life of the animal, but, like water, passes into it after life has left it, in consequence of its specific gravity. It is necessary, then, that we should attempt an explanation of the fact, why there should be so great a disproportion in quantity found in the lungs, on dissection after death? That from its pressure on the epiglottis, which is very great, it causes this valve to close, in a considerable measure, the aperture of the glottis, and then, from its immense gravity and power of attraction of aggregation, it forces its way through the most capable passage for receiving it, which is evinced to be the œsophagus, from so considerable a disproportion discharged per anum, together with that found in the stomach and intestines, when compared to that found in the lungs. Hence we rationally infer the little probability of this fluid entering the cavity of the lungs during the efforts of the animal to inspire.

When we reflect on the result of the above experiments, it is impossible not to perceive, with how much inaccuracy and incorrect judgment those authors were influenced, who attributed the death of animals from submersion, to the small portion of water found in the lungs, which phenomenon is so far from acting as the immediate cause of death, that it occurs after the exhaustion of the capacity for life.

That some fluid may enter the wind-pipe, during the efforts and struggles of the animal to inspire, I do not pretend to deny; but that it is thrown out again before it reaches the lungs, is obvious from the result of our expe-

riments. The very great irritability of the trachea and its appendages, is sufficiently known. Almost every one has experienced it, when by accident a single drop of any kind of fluid or other substance falls into the wind-pipe (or wrong throat, vulgarly called); the effect is a violent convulsive action in the part, which lasts until the foreign substance is again rejected, attended with severe coughing and irritation in the parts.

This must strike every one as a wise provision of the God of nature, to protect those highly important organs (the lungs), to prevent their receiving the impression of any other matter, than that of their natural stimulus, air. Had this wise protection been neglected by nature, animals could not live: For to breathe and to live are inseparably connected; our lungs would have been made, at every meal, a temporary stomach.

As we cannot positively deny that water may enter the cavity of the lungs, during the efforts to inspire, as a casual circumstance, which, although contrary to the result of our experiments, we will admit, for argument sake, and proceed to examine its effect upon the healthy animal.

EXPERIMENT XIV.

With a strong syringe, to the end of which was fixed a long curved tube, from two and a half to three ounce measures, of a weak solution of sulphate of iron, was forcibly thrown into the cavity of the lungs of a large pup, by placing the tube in the larynx, having had his mouth sufficiently extended by an assistant. He was set at liberty after the operation, and appeared to labour under considerable distress, convulsive action in the trachea very great, with the effect of throwing up some of the solution, respiration deep and laborious, and other violent symptoms, but which abated after a while. He was permitted to live twelve hours in this situation, at the expiration of which time he appeared to have nearly recovered. His trachea was now laid bare, and a ligature ap-

plied. On dissection, after death, I procured from his lungs three ounce measures of a frothy fluid, from which I separated two ounces of the solution, which was tested by the prussic acid and alcohol of galls. Experiments similar to this were performed on the same kind of animals, by injecting quicksilver into the lungs, through apertures made in the windpipe, but with results so similar (differing only in degree,) that I do not deem it necessary to relate more than one of them.

EXPERIMENT XV.

Doctor Jacobs having punctured the trachea of a half-grown pup, I introduced my tubulated syringe, holding two and a half ounce measures of a solution of sulphate of iron, all of which was forcibly discharged into the lungs, and repeated a second time, after which the external wound was closed up, and the animal set at liberty. A violent coughing, attended with small and quick respiration, ensued, and other violent symptoms, which continued for several hours. This operation was performed on Monday morning, at ten o'clock. At five in the afternoon, I left him much better. On Tuesday morning I returned, and found him walking about; the violence of the symptoms had entirely disappeared. At ten, this morning, having been permitted to live twenty-four hours, a ligature was passed round his trachea, and suffocation instantly produced. From his lungs, on dissection, I procured two and a half ounce measures of the solution, the other portion having been thrown up, by the violent efforts made by the parts to relieve themselves.

Here we are fully convinced, by experiment, that the same quantity of fluid found in the lungs, after death from drowning, when thrown artificially into those organs of an animal, that is allowed to respire during the process, produces very inconsiderable effects, the animal experiencing very little disadvantage from labouring under its influence for twelve hours, and most probably would have completely recovered in a short time. This fact tends

much to prove what we have been taught in this university, by Professor Rush, when treating of pulmonary state of fever, that the lungs are not such tender organs as is generally supposed.

Another class of writers having attributed the immediate cause of death, from submersion, hanging, &c. to apoplexy, among whom stands the ingenious Mr. Kite, we will have recourse to experiment to discover the truth of this position, which, from the result of all the preceding experiments, appears to be weakly founded; for dissection has never discovered to us, in any one instance, any thing like the appearance of apoplexy. The vessels of the brain having never been found turgid, no extravasation, nor effusion existing, and finally, very little more blood than natural in the head.

If the period of death is influenced by an accumulation of blood in the brain, in consequence of a temporary stoppage of its return from that organ to the heart, we will expect to find a considerable change produced, in respect to the protraction of that period, which we have observed to be in from one to four minutes, by diminishing the quantity of blood sent to the head and brain, in a given time, and then to submerse the animal.

EXPERIMENT XVI.

At eleven o'clock, assisted by Dr. Jacobs, the two carotid arteries of a half grown dog were laid bare, and firmly secured by ligatures. The external wound being now stitched up, the animal was set at liberty, and went about as usual, apparently as though nothing had been done to him. At five in the afternoon (no change having been produced on him by the operation, having the perfect use of all his functions, and appearing as lively as he was before the operation had been performed), he was plunged under water, and confined below its surface, not allowing him to respire the least portion of atmospheric air. His struggles and efforts to inspire were very strong, and continued for two minutes, after which he became feeble, and was

taken out dead in three minutes and five seconds. On dissection, the external surface of the brain appeared somewhat dark; very little blood was found in its vessels, which were but little more than half full of black blood. This experiment* was repeated on two other dogs of the same size, and in both instances the animals died in three minutes. On dissection, the sinuses of the brain were found about half full of black blood, and the substance of the brain perfectly natural, having no extravasation between its coats, nor any effusion in the cavity of its ventricles.

Thus we observe, that the communication through which the greatest portion of blood is sent, in a given time, from the heart to the head and brain, is completely cut off, and its impetus to that organ considerably diminished. It must be supposed, that the pressure on the brain, admitting there was any, must have diminished in proportion; but

* On the 16th of March, assisted by Dr. Jacobs, I firmly secured, by ligature, the two carotid arteries of a half grown dog, and by that means completely obstructed the passage of blood through them to the head and brain. The ligatures were applied about an inch and one fourth below the thyroid cartilage of the trachea, a considerable space from the place of its giving out the external carotids. This experiment was made with a view to discover, whether life and health were materially injured, by taking up these vessels. The animal appeared to labour under no disadvantage, except the wound and irritation excited in the parts, by the ligatures, which, however, sloughed off in a few days, and the wounds were perfectly healed by the 30th. He was very fat at the time the operation was performed, and continued so throughout the experiment. He had the perfect use of ALL his FUNCTIONS; and in fact, he appeared to have experienced not the smallest disadvantage from it, either in body or intellect. Desirous of seeing the appearance of the arteries, and to dispel all doubts relative to the complete obstruction to the blood circulating through them, on the 19th of May, he was hanged, when he died in three minutes; and on dissection, both of the arteries, immediately where the ligatures had been applied, appeared indurated, and, on introducing a small wire probe, was found to be completely obstructed. This singular fact may, in time, lead to something of considerable importance in medecine, in the treatment of diseases of great morbid action in the brain, and tends much to impress upon our minds the propriety of taking up those arteries (provided the aid of a surgeon is immediately at command) to save life, in cases where they have been divided, either by accident or design.

we find, notwithstanding this very great diminution of the supposed cause of death, that its period is not in the least retarded, varying not the space of one second, as will appear by referring to several of the preceding experiments.

We have now diminished the quantity of blood sent to the brain in a given time, without the effect of protracting life; we shall now, in an equal degree, obstruct its returning from that organ, which appears to promise death immediately.

EXPERIMENT XVII.

On the 20th of March, at ten o'clock, having laid bare the external and internal jugular veins of a half grown dog, on each side of his neck, ligatures were applied, and the external wound closed. He was now set at liberty. In one hour and thirty minutes, the animal appeared drowsy, but respiration still natural, with some increase of fulness in the pulse. In three hours, he appeared to desire sleep, and the blood vessels of the coats of his eyes were somewhat turgid. I left him lying on some straw at five in the afternoon, apparently better; at ten the next morning, found him much better, and his apoplectic symptoms not so evident as they were the day before. At twelve to-day, he was plunged under water, and confined below its surface during the whole time, not permitting him to have access to the external air. He struggled severely for two minutes, making frequent efforts to inspire. He now became very feeble, but still attempting to inspire, when he died in three minutes, according to the observation of my friend Mr. Nelson, who held a stop watch. On dissection, the blood vessels of the brain were very turgid, with extremely black blood. No extravasation occurred, but effusion had taken place in the ventricles. The lateral sinuses were traced to their termination in the jugulars, considerably distended, and the jugulars, above where the ligatures had been applied, were also much distended.

The same experiment, assisted by Dr. Jacobs, I repeated on another dog of the same size, who for

the space of five hours laboured under more violent symptoms than the other, but which abated in the course of the subsequent night, being able to walk about in the morning, and eat some flesh. He was allowed to live, under these circumstances, for three days, on the fourth, in the morning, having now almost perfectly recovered, he was plunged under water, in the presence of Dr. Jacobs, who held the watch. His efforts to escape were violent, which lasted for two minutes and ten seconds, after which he appeared very languid, but still making efforts to inspire. He was then taken out apparently dead in three minutes and ten seconds, and placed upon a table for dissection; during the space of time I was employed in making preparation for it, he was observed by one of the gentlemen present to make an effort to inspire, which rapidly increased, and in the course of two hours he recovered so as to walk about, which he did to get near the stove; this was at twelve o'clock on Saturday—at five in the afternoon, I left him as well as he was before submersion. On Sunday at twelve o'clock he was a second time plunged under water, when he died in three minutes and five seconds. On dissection the appearances exhibited were exactly similar to those stated in the other experiment, only differing in degree.

To ascertain the capacity of the vertebral vein, the only passage through which the blood could have been returned from the brain to the heart, in consequence of all the jugulars being secured by ligatures. The superior vena cava was injected, which discovers to us the vertebral vein, which we traced to its entrance through the foramen magnum of the occipital bone, about a third part of the size of the internal jugulars, and which appeared to have been considerably distended from the thinness of its coats. From the the smallness of this vein (having discovered but one) the volume of blood returned through it, from the brain, in a given time, is very inconsiderable, when compared to that returned through the jugulars. Hence, professor Monro observes‡, "when we consider that the

‡ Vide his book on the Nerves, page iv. sect. ii.

vertebral arteries are accompanied by small veins only, and, of course, that almost the whole blood which these as well as the internal carotid arteries convey, is returned by the lateral sinuses and their continuation, the internal jugular veins." Now, these vessels being completely obstructed, it must follow, of course, that the congestion produced in the brain, must be considerable, which is the fact.

From these researches, we are then satisfactorily convinced of the impropriety of attributing death in drowning to apoplexy, admitting the small quantity of blood found on dissection after death, could produce it. For we have here had ocular demonstration, that the animals laboured under a considerable degree of congestion and compression of the brain, (in consequence of the return of blood through the jugulars being obstructed) with very little disadvantage for the space of from twenty-six hours to three days, and that the period of death on submersion was not in the least degree facilitated by it. No force of argument is here required to overthrow this hypothesis, which we have, at the shrine of experiment, proved to be void of foundation.

To discover under what degree of collapse of the lungs an animal could live and have his circulation perfect, when allowed to respire, the following experiments were made, under the immediate inspection of several of my fellow candidates, and with a view to ascertain how far death from drowning, was influenced by a collapse of the lungs, preventing a free circulation of blood through them.

EXPERIMENT XVIII.

Having secured a half grown dog upon the table, an incision was made on each side of the thorax under the axilla, down to the intercostal muscles, with a broad pointed scalpel; I then made a preforation into each cavity of the thorax, (taking care not to wound the lungs in the operation) sufficiently large to admit two of my fingers, with which I could distinctly feel the heart in strong and regular motion. Immediately on making both preforations, the

lungs were observed to collapse to a considerable degree, from the pressure of the external air. The animal was now set at liberty, when he walked about with more ease than would have been expected. The external air had now free access to the surface of the lungs, through the perforations, and when forced out of the cavity of the thorax, by the strong expirations of the animal, made a considerable noise, respiration deep and laborious, and apparently attended with much pain. It is now five hours since the operation, and the animal is just the same as he was the first minute after it, I again introduced my finger, and found the lungs much collapsed, and during the expirations fallen on the ribs and intercostal muscles; no adhesion whatever could be discovered between the lungs and the contiguous parts, and the motion of the heart still very strong. The apertures were now sufficiently enlarged to admit my seeing distinctly the circulation through the lungs, during the expirations of the animal, which were long and quickly succeeded by deep and forcible inspirations. I could very plainly observe the red blood circulating through the pulmonary veins to the left auricle, the veins did not appear to have diminished in diameter for the degree of collapse existing. The animal was allowed to live in this situation for twenty-four hours, at which time he appeared somewhat more easy than he did two hours after the operation. The temperature of his body, before he was operated on, was equal to ninety-six of Fahrenheit's thermometer, at which standard it continued throughout the process. At twelve o'clock, the subsequent day, his trachea was laid bare, and at the immediate termination of an inspiration, it was closed, the animal died in two minutes. The lungs were now carefully removed from the thorax, with the ligature remaining round the trachea, to prevent any communication between the atmospheric air and that contained in the lungs. They were now placed under a tumbler filled with water, and inverted over the pneumatic tub, after which the ligature was removed, and the air they contained forced out by pressure, which was found to be three and a half cubic inches.

EXPERIMENT XIX.

Assisted by Dr. Jacobs, on the 25th of March, at ten o'clock, a perforation was made into each cavity of the thorax, by cutting through the intercostal muscles, between the cartilages of the ribs, in length one and a half inches, observing to avoid wounding the substance of the lungs, which were again observed to collapse from the pressure of the external air. The Doctor now introduced his finger, and felt the heart in strong and regular action; the same symptoms ensued here as related in the former experiment, but in a more violent degree. The temperature of this animal was ninety-eight of Fahrenheit's thermometer, he was made to lay upon his back, after the operation, for one hour, when the inflation of the lungs could, very distinctly, be seen, externally at every inspiration, which were very strong. No connection between the lungs and the surrounding parts, could be felt when the finger was introduced. In five hours after the operation, the heat of his body at ninety-eight; he now walks about, but apparently breaths with much difficulty and pain. At five o'clock this afternoon I left him lying on some straw, appearing to respire with more ease. On the 26th, at ten, the thermometer was applied under the left axilla standing at forty-five—it rose to ninety-eight; the violence of the symptoms under which he laboured on the 25th had abated considerably during the night, respiring this morning with apparently more ease, the inspirations are still deep and strong, attended with occasional coughing. The lungs were now examined by introducing one of my fingers, with a view to ascertain, if there were any adhesions formed between them and the contiguous parts, but I could not discover the least. On the 27th, at ten o'clock, they were again examined, and were discovered to be in a state of recent inflammation, with some slight adhesions to the intercostal and diaphragm muscles. To relieve the poor animal from his misery, at ten this morning, his trachea was laid bare, and a ligature passed round it, which, at the end of an inspira-

tion was closed, and life with it, the animal dying in one minute and fifty seconds. The sternum, together with the cartilages of the ribs, were now removed, which discovered to us the lungs much collapsed, and in a state of inflammation in several places. The adhesions were observed to be very slight, and appeared to be altogether the effect of inflammation. The lungs were now carefully dissected from the body, with the ligature remaining round the trachea, after which the air they contained was procured from them in the same manner as related in the other experiment, and was found to be two and three-fourths cubic inches.

From the result of these experiments, we infer, that no greater degree of collapse of the lungs occurs in death from drowning, than took place in these two animals from the pressure of the external air, as will be evident by comparing the quantity of air procured after death from their lungs, in the manner above mentioned, with that obtained from them after drowning, which we have said in some of our preceding conclusions to be from one and a half cubic inches to fifty, and that in proportion, as we have already observed, to the capacity of those organs, which were greater in these last two animals, than they were in several of those that were drowned; notwithstanding which, the quantity of air discovered in the lungs, is somewhat less; hence the collapse must have been greater, and the obstruction to circulation in proportion, (according to the theory of collapse,) but which we observed during the experiment, to be very inconsiderably impeded, if any at all, for the blood still receiving the oxygenous principle from the air inspired, continued to exert its natural action of the heart and arteries, keeping up a strong circulation, for the space of from twenty-four to forty-eight hours.

That a considerable collapse of the lungs does actually take place in drowning, is proved by experiment, but it is equally the fact, demonstrated by the same experiments, that a complete collapse does not occur. Here the considerable difference between the result of these experiments, and those related by the ingenious Mr. Coleman is obvious, when that author reports that he could never ob-

tain from the lungs, on dissection, after death from submersion, more than from a half to two drachms of air. Hence the origin of his supposed cause of death, which position we have now discovered by experiment not to be founded on fact, and which we will set down in his own words, " To us, therefore, the proximate cause of that disease produced by drowning, hanging, and suffocation, appears to be mechanical obstruction in the interior pulmonary vessels from collapse of the lungs;" to which he adds, " with a want of latent heat in the blood;" and again says, " for remove this collapse, and induce the necessary change on the blood, and you cure the disease."

Here the author must have been convinced of the extreme impropriety of supposing that the degree of collapse discovered on dissection, could have any share in producing death, for, in the first place, we find it does not take place to that degree, which he would induce us to believe (from perhaps inaccurate observation), and secondly, if the proximate cause depended upon " mechanical obstruction from collapse," we ought to be able most indubitably to restore life, where the capacity for it remained, on removing the collapse by inflating the lungs with fixed air, azotic gas, inflammable air, &c. &c. which is not possible, and of which fact the author appears to have been aware, from his observation above, relative to the modus curandi. It is obvious, then, that life cannot be restored before the blood has received its oxygenation, of which it had been completely deprived during submersion. For it is a fact, that the lungs may be inflated, and the pressure on the vessels (admitting there existed any) removed, by means of any aeriform fluid, without the effect of restoring motion to the heart and arteries, provided we apply no oxygen gas at the same time.

This last mentioned author (Mr. Coleman) in attempting to refute the position of Dr. Goodwyn, relative to the specific action of red blood on the left auricle and ventricle of the heart, adduces as an argument to support his opinion, and refute that of the doctor, the circulation of the blood in fishes, which he says is kept up by the stimu-

lus of black blood. To discover the foundation for this apparently false fact, the following experiments were made.

Having procured several fish, which were of the same genus, and nearly equal in size, I committed one to dissection, while alive. As soon as the heart was laid open to full view, I could distinctly see its action, which continued for a length of time, with considerable force and regularity. The blood was observed to enter the auricle of a colour not quite so florid as that of warm-blooded animals, and which was observed, when circulating through the liver, to resemble, in colour, venous blood. The heart was viewed through a magnifying glass, for a length of time, during which the circulation of red blood continued without interruption. Another* was treated in the same way, and with similar results. They both respired frequently during the operation.

Thus we may infer, that the same changes, produced on the blood, in circulating through the lungs of quadrupeds and other animals, by respiration, is effected on the blood of these aquatic animals; and certainly for the purpose of effecting the same end†.

* A third fish was plunged into a glass vessel filled with, and inverted over water, in the pneumatic tub, so as to exclude all communication with the external air. He was taken out dead in ten hours.

A fourth was allowed to swim at liberty in water of the same temperature, contained in a large tub. He remained in this situation for three days, at the expiration of which time he was taken out perfectly alive, and was plunged under water highly impregnated with fixed air. During the process of submersion, he was not allowed to rise to the surface; he made frequent attempts to inspire: he was taken out dead in six hours.

Another fish was plunged under spermaceti oil contained in a glass vessel: he was taken out dead in six hours and thirty minutes. On dissection, they all exhibited the same disoxygenated appearance.

† A knowledge of the immediate dependence of animal life upon the consumption of this gas (vital air) through the medium of respiration, was familiar to our ancestors in medicine. "The air is the fewel of *vital flame* without which it would speedily languish and go out." Again, the same author observes, "Fishes, and other water animals, cannot support life with-

Doctor Goodwyn, in his ingenious work, entitled "Connexion of life with respiration," after numerous experiments, concludes, that in consequence of obstructed respiration, the blood is deprived of that quality communicated to it by the oxygenous part of the atmosphere, in which resides its power of action, on the left side of the heart; the effect of which privation is a defect in its stimulant power, rendering it incompatible to the exciting of action in the left auricle and ventricle.

This theory appears, from the result of our experiments, to be the most rational, and on which we will now proceed to make some observations. If the immediate cause of death is a disoxygenation of the blood, depriving it of its red colour (arterial blood) we will expect to find animal life supported under water, in proportion to the quantity of this fluid, assisting in the system, at the time of submersion. To ascertain which the following experiments were made.

EXPERIMENT XX.

Having procured seven kittens, of the same litter, and nearly equal in size, my friend, Mr. Nelson, holding a stop watch, I exposed two of them to the action of oxygen gas, contained under a glass vessel, inverted over the pneumatic tub, (obtained from the black oxide of manganese by heat) for the space of ten minutes, after which they were both plunged under water, and struggled for six minutes, when they became feeble, and were taken out, apparently dead, in seven minutes and fifty seconds. The third was treated in the same manner, with similar results, varying only in degree; on dissection, the heart was still contracting, and retained its irritability for a very considerable time, in two instances for the space of five hours.

The fourth and fifth were plunged under water of the same temperature, in a natural state, and were taken out, appa-

out it; for if you put your hand or any covering over a vessel containing fish, so as wholly to exclude the air, they will be suddenly suffocated."

Ray on the Wisdom of God, manifested in the Works of Creation, page 72.

rently dead, in three minutes and ten seconds, but, on dissection, the heart was still contracting, though being feeble, and ceased altogether in a few minutes.

To ascertain how far any peculiarity of constitution may have tended to prolong life in these experiments, the remaining two kittens were plunged into water, in a natural state*, and were both of them taken out dead in three minutes and thirty seconds. Hence we can infer no inaccuracy on that head.

Desirous of being very accurate with these experiments, I procured four pups of the same litter, prefering them to young kittens, from their being less tenacious of life, and on that account more analogous to the human species.

EXPERIMENT XXI.

Having procured four pups, I plunged two of them into an atmosphere of pure oxygenous gas, (tested in the eudiometer) and confined them in it for the space of ten minutes; at which time they were both submersed, taking care not to permit them to respire atmospheric air, during the process. They both struggled with considerable force for seven minutes, and were taken out apparently dead, the first in eight minutes and thirty seconds; and the other in nine minutes. The irritability of the heart was still considerable, which continued to contract for several hours after dissection.

The remaining two were plunged into water of the same temperature, in a natural state, and were taken out apparently dead in two minutes and forty seconds; and on dissection, the heart was still irritable, but retained it only a short time.

We are thus fully convinced, by comparing the result of these experiments, that the considerable difference in the period of death, could not have been influenced by any peculiarity of constitution, or other circumstances, but

* By a natural state, I mean that which has not undergone an artificial change.

depending on the oxygenation of the animals, which were caused to respire this gas, before they were submersed. Hence we conclude, that animal life is actually supported under water in proportion to the oxygenation of the system at the time of submersion.

To ascertain how long an animal could live under water, when permitted to respire, by means of a tube, through which the external air is allowed to have access to the lungs, the following experiment was made.

EXPERIMENT XXII.

After laying bare the trachea of a large dog, a perforation was made into it, large enough to admit the small end of a long curved tube, about the size of a large goose quill, after some little difficulty the tube was placed in the canal of the wind-pipe, and a strong ligature was immediately applied, including it very firmly in this situation. The large end of the tube now communicating with the external air, the animal was plunged under water, and confined below its surface during the process. In this situation he continued to breathe, apparently without much disadvantage (except the considerable irritation excited in the trachea by the tube, which caused him to struggle much) for one hour, his pulse at first was frequent and weak, from the operation of fair, and the sudden change of temperature, but returned to its natural action before the expiration of the hour. The large end of the tube, communicating with the external air, was now completely filled up with soft wax, cutting off the access of air to the lungs; the animal became immediately affected by it, struggling with considerable force, and making repeated efforts to inspire, without being able to effect it. He was taken out dead in three minutes and ten seconds, and, on dissection, exhibited the same disoxygenated appearances, as we have related in several of the preceding experiments. This experiment was repeated on another dog of the same size, the results were similar.

We thus observe, that an animal can live and have his circulation perfect, for the space of one hour under water,

(during which time he appeared to labour under very little disadvantage), when he is allowed to respire, in the manner related above, and very probable would live for whole days in this situation—provided food could be conveyed into his stomach. But immediately on obstructing the passage of air to the lungs, death takes place. Hence the propriety of saying, that the water or other fluid in which animals are unfortunately drowned, produces no other effect than that of indirectly cutting off the communication between the lungs and the external air, which is followed, in a few minutes, by a disoxygenation of the blood, the effect of which is either a diminished irritability of the heart, which is still reparable, or an exhaustion which constitues death.

We shall now, with a view to discover the relative effects of inspiring at different times, equal portions of pure oxygenous gas, and atmospheric air, make some experiments on the human respiration.

EXPERIMENT XXIII.

Having occasionally, for several days, accustomed myself to suspend my respiration after making inspirations of twenty-five cubic inches of atmospheric air, I was able, after frequent repetition and perseverance, to suspend it to the extent of one minute and ten seconds, beyond which I could not possibly extend it: and to arrive at that was a matter of no small difficulty, for at first I was only able to suspend it for thirty seconds, but, by perseverence, I gradually increased the time from thirty to thirty-five, to forty-five, to fifty, and, with the greatest distress, to seventy seconds, at which time I was scarce able to stand, my face purple with a sense of fulness about my head, and considerable depression across my chest. Having some oxygenous gas at hand, an inspiration of it was taken, when, in a few seconds, the disagreeable symptoms were dispelled.

I omitted this disagreeable mode of experimenting for several days, so that the result of the following should not be influenced by habit.

EXPERIMENT XXIV.

I inspired twenty-five cubic inches of pure oxygenous gas, obtained from the black oxide of manganese by heat. The stimulant effect of this gas was soon perceived, it diffused a pleasurable degree of warmth through my body, and quickened my circulation. Having a stop watch before me, I observed I could, with considerable ease, suspend my respiration for three minutes with this portion of gas, which, on being expired, was received into a glass vessel filled with water, and inverted over the pneumatic tub, a portion of it was now mixed with nitrous air contained in the eudiometer, which formed a small portion of nitrous acid vapour, indicating the presence of oxygen gas. It must here be observed, that the air expired in experiment XXIII, after suspending the respiration for seventy seconds, was also tested in the same manner, but not the smallest portion of oxygen gas could be detected, it likewise instantly extinguished a taper when plunged into it.

Here we observe, in experiment XXIII, the same effects produced on the human body (differing only in degree) from suspending the respiration for the space of only one minute and ten seconds, during which time the portion of oxygen contained in twenty-five cubic inches of common atmospheric air, (which is allowed to be seven,) was entirely consumed, and was succeeded by the same symptoms observed externally to take place during submersion, in which death occurs in from two to three and four minutes.

From the experiments of M. De La Metherie,* which are allowed to be very accurate, we are told that an animal consumes, in the space of one hour, three hundred and sixty cubic inches of oxygen gas, (but which consumption, I think, must be in proportion to the size of the animal) this calculation we will apply, however, to the respiration of a stout robust man, who we will suppose in drowning, immediately before he sinks the last time, to make an inspiration of one hundred cubic inches of atmospheric air and allow him to retain this portion until death, which is not the case.

* See Chaptal's Chemistry.

His system will become completely disoxygenated in the space of four minutes, forty-one and three fourths of a second, admitting he had taken in with the hundred cubic inches the twenty-eight of oxygen, allowed to be contained in that volume of atmospheric air.

Here then we see, that exhaustion of irritability of the heart is, in many instances, immediately subsequent to a disoxygenation of the blood; but the muscular fibres of different animals retain it a longer or a shorter time, accordingly as they part with it with more facility.

We will apply the calculation of Mr. De La Metherie to the respiration of smaller animals. The greater part of the animals, the subjects of these experiments, would inspire, immediately before they were plunged under water, a volume of air not less than twenty-five cubic inches. Now, in twenty-five cubic inches of atmospheric air, there is allowed to be seven of oxygen gas, in mixture with eighteen of azotic; and if he consumes three hundred and sixty cubic inches in an hour, we infer, that eleven and one fourth cubic inches is indispensably necessary to support life for the short space of one hundred and twelve and a half seconds, or one minute and fifty-two and a half seconds. Here is at once a deficiency of four and a quarter inches of the given quantity consumed, in the given time of one minute, fifty-two and a half seconds. Hence the animal dies in from two to three minutes, perfectly disoxygenated.

From the result of several dissections, after death from hanging, in which appearances were analagous to those which we discover after death from drowning, we cannot but infer the nature of the disease to be the same, and that the extinction of life is effected in the same way.

EXPERIMENT XXV.

Having laid bare the trachea of a large dog, a perforation was made into it, large enough to admit a canula, about the size of a large goose-quill, which was firmly secured in it by a ligature. He was now set at liberty, ap-

pearing not to labour under any other disadvantage, than the degree of irritation excited in the trachea by the tube. At the expiration of thirty minutes, during which time he respired with but little interruption, a noose was applied round his neck, above the puncture, after which he was suspended in that situation for one hour. He struggled but very little, continuing to breathe, during the process, through his artificial wind pipe. Another ligature was now applied, below the puncture in the trachea, completely obstructing the passage of air into the lungs, when he died in three minutes and twenty seconds.

EXPERIMENT XXVI.*

Assisted by my friend Mr. Grimes, the trachea of another dog was laid bare, and treated in the same manner; after which a ligature was applied round his neck, above the opening, and on being pulled by two persons, was closed to a considerable degree, more so than if the animal had been suspended or hanged. During the process, he continued to breathe almost as usual, and rose up repeatedly, having a desire to walk. In this situation, he was allowed to remain for one hour, after which a second ligature was passed round his neck, below the opening made in the trachea, when he died in three minutes. The irritability was still perceptible in both of them, but was very feeble, and continued only for a few minutes.

Thus we are fully convinced, that an animal may be suspended by the neck, for the space of one hour, without receiving any considerable injury from it, provided he is allowed to respire in the manner related above, during the process; but as soon as the admission of air into the lungs is cut off by ligature, we observe the extinction of life follows, in from three to four minutes, exhibiting, on dissec-

* The illustrious Professor Munro, of Edinburgh, made an experiment, similar to the above, with nearly the same results. Vide Munro on the nerves, p. 7, sect. viii.

tion, the same disoxygenated appearance of the blood, as that discovered on dissection after death from drowning.

We will now turn our attention to another subject of this essay, which is highly interesting, and one which merits more investigation than I have at present time to bestow on it....which is suspended life, from the action of unrespirable airs on the animal body;....viz. hydrogenous gas, azotic gas, carbonic acid gas, and lastly, the carbonated hydrogenous gas.

EXPERIMENT XXVII.

Mr. Foissin holding a stop watch, I plunged a half grown pup into an atmosphere of inflammable air (contained under a large glass vessel, inverted over water, in the preumatic tub, and obtained from the decomposition of water.) In two minutes, he is not much affected, respiring almost as usual; in five, he moves about briskly in the vessel, making a yelping kind of noise, and seeming desirous to escape; in seven, respiration laborious, which increased rapidly; and in eight, ceased altogether. The animal was taken out apparently dead, in fourteen minutes. On dissection, the heart was discovered to be in motion, but was very weak, and it ceased to move at all in a few minutes. The blood in both sides of the heart was black, and more accumulated in the right than left side. The lungs were found somewhat collapsed, but containing a considerable portion of gas, which was tested in the eudiometer, and was discovered to be inflammable air, in mixture with carbonic acid and azotic gases. Another dog, of the same size, was treated in the same manner, with another portion of gas, and died in fifteen minutes and ten seconds. On dissection, the irritability of the heart appeared to have been perfectly exhausted, by the action of the gas during the process, the blood in both sides of the heart, and all through the body, of a dark colour, indicating a privation of oxygen.

TO ASCERTAIN THE COMPARATIVE EFFECTS OF AN ARTIFICIAL ATMOSPHERE OF THIS GAS COMBINED WITH OXYGEN GAS, ON THE ANIMAL BODY, WITH THAT PRODUCED BY INFLAMMABLE AIR ALONE, THE FOLLOWING EXPERIMENTS WERE MADE.

EXPERIMENT XXVIII.

After mixing with seventy-two parts of hydrogen gas twenty-eight of pure oxygenous (by agitating them together in a large glass vessel, inverted over water), I exposed two pups, about four weeks old, to its action. In eight minutes, they both appeared not to be much affected by it, respiring as usual, but in fifteen minutes scratched the sides of the vessel, as if desirous to escape. In this situation they remained for twenty-five minutes; after this they were taken out. The first was then plunged under water, and was taken out apparently dead in three minutes; but on dissection, the heart was still contracting, and the blood somewhat brighter than it was in the two which were killed in hydrogen alone. The other was set at liberty, and perfectly recovered in the course of a few hours. Here the effect of oxygen, in supporting life in these animals, is striking.

From these results we infer, that life was supported, in the two last experiments, by the oxygen gas, contained in the artificial atmosphere, keeping up the oxygenation of the blood (during the process), which in those that were killed in hydrogen alone, as we have noticed, was black, and the irritability nearly exhausted; while in these it was somewhat florid, the motion in the heart strong, and which continued for a length of time.

EXPERIMENT XXIX.

Having procured a large quantity of azotic gas, from nitric acid and fresh muscular flesh, two pups were plunged into an atmosphere of it (contained under a glass vessel, inverted over water in the chemical tub). They both struggled severely, appearing to labour under considerable distress, about the region of the thorax. The first died in eight minutes and ten seconds, the other in ten minutes.

On dissection, the lungs were found about half collapsed, and resembling, in many places, an ecchymosis, the blood throughout the body of a dark colour, resembling venous blood, and the irritability of the heart nearly exhausted. The lungs appeared to have laboured under the influence of the nitrous acid vapour, formed by the azote uniting to the small portion of oxygen present in the lungs, at the time the animals were plunged into the azotic gas.

These experiments were repeated on several young kittens, with similar results.

We shall now proceed to make some experiments on the suspension of vital action from carbonic acid gas; which do not unfrequently prove a source of human misery, being found so plentifully generated in domestic places.

EXPERIMENT XXXI.

Having procured three pups of the same litter, and about three weeks old, viz. A. B. and C. they were all exposed nearly at the same instant (a few seconds intervening) to the action of carbonic acid gas, contained under a spacious glass vessel inverted over water in the chemical tub, and procured from powdered marble and sulphuric acid. In ten seconds they are not much affected, respiring with ease; in twenty began to grow uneasy, making efforts to escape; in forty seconds becoming furious, respiration laborious, and appearing to labour under considerable distress about the region of the thorax, pulsation in the heart now quick and full; in one minute they were all furious, scratching the sides of the vessel with considerable force, in two minutes the difficulty of respiration much increased, pulse now diminished in quickness, but not in fulness, becoming slow and full. These violent symptoms rapidly increased for three minutes, when they became very feeble and relaxed. None are now able to inspire, except C. who respires occasionally; in four minutes they are all very languid. No efforts are now made to inspire, and all of them except C. who still moves about, though very feebly, appearing to be in a state of torpid insensibility, evincing no sensation on being pinched with the point of a sharp

instrument. A. and B. were taken out dead in four minutes and thirty seconds. On dissection no signs of irritability could be discovered in the heart of A. and B. to which the galvanic influence was applied; but in that of C. there still remained some, though very inconsiderable, which lasted but for a few minutes. The blood in both sides of the heart, the pulmonary artery and veins, was perfectly black, and much accumulated. The lungs were about half collapsed, and of a darker colour than natural. The air contained in them was forced out by pressure and received into separate vessels....From the lungs of A, I procured one and a half cubic inches, from B, one and a quarter, and from C, one and three quarters; after which each portion was tested separately by the eudiometer; but in which I could detect not the least portion of oxygen gas, a portion of it was then sent up through a column of lime-water contained in a glass tube, when a considerable precipitation of the carbonate of lime took place.

My friend Mr. Walmsey holding a stop-watch, I plunged a large rat into the same portion of gas, which died in three minutes and forty seconds. On dissection the irritability of his heart was still perceptible, but continued for only a few minutes. Other appearances were the same as those related above.

The brain in these experiments was observed to be perfectly natural; no turgescence of its vessels, as has been reported to take place, could be discovered, and, though full of black blood, they were never found in a state of moderate distension.

My fellow graduate Mr. Nelson attending to the watch, I plunged two pups of the same size, and about six weeks old, into an atmosphere of concentrated fixed air, contained under a large glass vessel, which I was forced to press down with my left hand, to prevent its upsetting from the pressure of the gas, which was very pure, extinguishing a taper, when poured from one vessel into another. The symptoms enumerated in the preceding experiments occurred here to a violent degree, and lasted for three minutes and thirty seconds, after which they became very feeble, and so relaxed that their

heads were obliged to be supported above the water, to prevent their drowning, and in four minutes one was taken out dead, the other still shewing signs of life, but died in four minutes and thirty seconds. On dissection nothing like congestion in the vessels of the brain could be discovered. The superior longitudinal and lateral sinuses contained black blood but were barely full. The irritability of the heart was not perceptible, though operated on by the stimulus of the galvanic influence.

Although contrary to the result of experiments, as several authors have supposed that apoplexy is produced by the action of this gas, and have stated it as the immediate cause of death, we will put it to a test of experiment. If apoplexy has any share in producing death, as it consists in an accumulation and congestion of blood, in the vessels of the brain, producing extravasation, effusion, &c. &c. the effect of which is compression. We will rationally expect to find the period of death protracted by diminishing the quantity of blood sent from the heart to the head and brain in a given time, and vice versa, by increasing the accumulation and congestion of blood in the brain, we will certainly expect to facilitate the death of the animal, to ascertain which the following experiments were made

EXPERIMENT XXXII.

The carotid arteries of two large pups, C. and D. were laid bare and secured by ligature, just after they left the top of the thorax, after which the external wound was closed up, and the animals set at liberty; they appeared to labour under no disadvantage for the space of three hours, at which time they were exposed to the action of carbonic acid gas, contained under separate glass vessels, inverted over water, in ten seconds they are not much affected, in twenty some what so, making efforts to escape, in forty respiration laborious, and attended with much distress, pulse quick and full, in one minute they are furious, struggling with considerable force, and difficulty of respiring much increased. These violent symptoms increased rapidly for the space of three minutes, when they became very feeble, appearing to be in a sound sleep, but moving

occasionally; D. still making feeble efforts to inspire, in four minutes and five seconds C was taken out dead, and D in four minutes and twenty-five seconds. On examining the brain, very little blood could be discovered in its vessels. Its sinuses about half full of extremely black blood. No extravasation was found between its coats, nor effusion in its ventricles, the brain appearing perfectly natural.

EXPERIMENT XXXIII.

Having laid bare the external and internal jugular veins, of two pups, E and F, ligatures were passed round them with a view to prevent as much as possible the return of blood from the head and brain; the external wound was now stitched up, and the animal permitted to run about at large. In thirty minutes E appears somewhat affected, having a disposition to lay down; in forty minutes F appears drowsy, eyes dull and heavy, respiration is continued as usual; they were allowed to remain in this situation for a considerable time, during which evident symptoms of apoplexy occurred. At the expiration of three hours they were both plunged into an atmosphere of fixed air, contained under separate vessels. The violent symptoms already mentioned in the above experiments, occurred to a considerable degree in these, but were not perceptibly augmented. E was taken out dead in four minutes and twenty seconds, and F in four minutes and fifty seconds. On dissection the vessels of the brain were found extremely turgid with blood, particularly the sinuses, the vessels of the choroid plexus, considerably distended with black blood, and in the lateral ventricles was found a yellowish coloured fluid.

The inferences to be drawn from these experiments are very striking; they prove, in a satisfactory manner, the impropriety of attributing death to apoplexy, admitting it did take place. It is a fact which cannot be denied, that persons have laboured, for a length of time, under a considerable degree of compression of the brain, either from external or internal injuries, and have, at length, been perfectly recovered. Now, if a compression of the

brain, in such numerous instances, is not adequate to the extinction of life, though allowed to remain for so long a time, I would ask, why should it prove fatal to animals exposed to the action of this gas, in the short space of from three to five minutes?

Having, on dissection after death, from the action of this gas, discovered the same disoxygenation of the blood as occurred in those drowned in water; and showing that life was supported under water, in proportion to the quantity of this principle present in the body at the time of submersion, we will repeat the same experiments here, and observe the results.

After repeated and deliberate attempts were made to form an artificial atmosphere with fixed air and oxygen gas, by mixing them, from long and continued agitation, I found it impracticable: the carbonic acid gas, from its superior gravity, would in a short time fall to the bottom of the vessel. Wishing to avoid any inaccuracy on that head, I relinquished it altogether, and adopted another more certain mode, which was to hyperoxygenate the system of my animals, and then to expose them to an atmosphere of fixed air.

EXPERIMENT XXXIII.

Having procured six pups of the same litter, and about four weeks old, I plunged two of them into an atmosphere of fixed air. The first was taken out dead (after much struggling) in four minutes, and the second in four minutes and forty seconds.

EXPERIMENT XXXIV.

The remaining four pups, viz. A, B, C, and D, were afterwards treated in the following manner, having previously procured a quantity of pure oxygenous gas, from the black oxide of manganese by heat, which was contained under separate glass vessels, inverted over water in the pneumatic tub. The pup A was exposed to the action

of oxygen gas for ten minutes, after which he was plunged into a quantity of fixed air. He was taken out apparently dead in ten minutes and fifty seconds, but on dissection, motion in the heart was very perceptible, and continued for some time. B was exposed to oxygen gas for twenty minutes; he was then placed in fixed air, and was taken out apparently dead in fifteen minutes, but recovered without having any thing done to him. C respired oxygen gas for forty minutes, when he was plunged into an atmosphere of fixed air, and was taken out dead in thirty minutes. D was allowed to remain in oxygen gas for one hour, at which time he appeared somewhat feeble, from the action of the gas; he was then plunged into fixed air, and continued to move in it for thirty-five minutes, after which he was taken out apparently dead, but on dissection, the heart was still found to be in motion, which lasted for some time. The blood, on dissection of these animals, appeared somewhat florid, and thinner than natural.

From the above experiments we draw the following conclusions.

1. That from cutting off the communication of atmospheric air with the lungs, the blood is deprived of its florid colour, exhibiting the same disoxygenated appearance, as that observed on dissection after death from drowning.

2. That black blood is accumulated in the heart: also in the pulmonary artery and veins.

3. That the irritability of the heart and animal fibre, in some instances was so completely exhausted, as not to be perceptible on the application of the strongest excitants.

4. But in other cases, motion was still existing in the heart, which was sometimes kept up for a considerable time, by the stimulus of the galvanic influence.

5. That similar to those drowned in water, a torpid insensibility is observed to take place.

6. That no congestion takes place in the vessels of the brain, which appears perfectly natural.

7. That the lungs are not found in a state of perfect collapse, and on testing the air they contained (i. e. the air contained in the lungs of those, which were exposed to the action of unrespirable gasses, without being previously made to respire oxygen gas) not the smallest portion of vital air could be detected.

8. That animals placed in an atmosphere of these gasses do respire, for a longer or shorter time, which process is performed with considerable more ease in hydrogen and azotic gasses, than in fixed air.

9. That the calculation of M. de la Metherie, relative to the consumption of vital air in a given time, is applicable to the respiration of animals placed in these airs.

10. That it is an absolute fact (which was testified by several gentlemen, present at the time the experiments were made) that irritability and life was supported in an atmosphere of these gasses, in proportion to the oxygen present in the system at the time of experiment.

And lastly, That in justice to the test of experiment, we are compelled to acknowledge the modus operandi of these airs, in producing death, to be the same, and that operation to be a positive action on the irritability of the heart and muscular fibres.

OF THE HYDROCARBONATE GAS.

This carbonated inflammable air is said to be hydrogen gas holding carbon in solution, and can be obtained in several different ways. I procured it by extinguishing ignited charcoal under water, and receiving the gas as it would rise to the surface. To deprive it of the fixed air it usually contains, it is necessary to agitate in water for some time, when the fixed air will be absorbed.

* The successful application of cold to the body in recovering suspended life from the action of these airs, tends considerably to prove the stimulant effect they have upon the irritability of the heart and muscular fibre.

EXPERIMENT XXXV.

My friend, Mr. Thomas, attending to the watch, I plunged two pups, of three weeks old, into an atmosphere of this gas, contained under a glass vessel. In fifteen seconds, they were much affected, struggled hard, and making a noise similar to those exposed to oxygen gas; in twenty, respiration short, and pulse very quick, and more full than natural; in forty still the same, in one minute they were furious, pulse still quick and full; in one minute and thirty seconds they both became feeble, and more relaxed than I had ever seen them in fixed air, being obliged to support their heads above water, to prevent their drowning. In two minutes and thirty seconds the first was taken out apparently dead, and the second in two minutes and ten seconds, and on dissection exhibited the following appearances. The heart was observed to be still in strong motion, and a regular circulation was kept up for eight or nine minutes, which was indicated by dividing one of the intercostal arteries, when blood as red as scarlet was sent through it with considerable force; the lungs were of a beautiful florid colour, similar to those placed in oxygen gas. The blood throughout the body as red as scarlet, the two venæcavæ, the pulmonary arteries and veins, the jugular, the hepatic, and splenic veins, resemble so many chords of a bright red colour. The irritability of the heart continued for a length of time.

EXPERIMENT XXXVI.

In the presence of Dr. Roebuck and Mr. Grimes (the former gentleman attending to the watch), I plunged a pup of eight weeks old into a quantity of this gas. The animal struggled considerably, for one minute and twenty seconds, after which he became very feeble and relaxed, but still respiring occasionally. He was taken out apparently dead in two minutes and forty seconds. On dissec-

tion the heart was still in motion, and circulation went on for some time with extremely red blood; the liver appeared of a dull red, and the spleen of a bright red colour; the brain appeared natural, with its sinuses full of very red blood.

EXPERIMENT XXXVII.

In order to discover the appearance of the blood of a healthy animal, of the same kind, and nearly about the same age, the following experiment was made.

Assisted by Mr. Grimes, we removed the sternum of a pup, while alive, together with the cartilages of the ribs; after which we removed the pericardium, and laid the heart open to full view, which was still in regular and strong motion. The blood was seen passing through the pulmonary veins to the left auricle, of a florid colour, and was observed to be very black when returned from the extremities to the right auricle and ventricle. The animal died in a few minutes from the loss of blood.

EXPERIMENT XXXIX.

Doctor Rosseau attending to the watch, another pup was exposed to the action of this gas. He struggled violently for several minutes, respiring apparently with much distress; pulse full and frequent, and continued so for four minutes and fifty-five seconds; at which time it began to diminish in force, but not in frequency; the animal appearing to be in a calm sleep, but moved when stimulated to it. He did not die until seven minutes and fifty seconds, after which he was taken out and dissected, with results similar to those already related. Whether this difference in the period of death was in consequence of some peculiarity of constitution, or owing to the quality of the gas, I cannot say.

From observing the similarity of effect produced in the blood of animals, made to respire this gas, to that induced

by the action of oxygen gas, I was induced to investigate, still farther, these analagous effects on the animal body to that gas.

EXPERIMENT XL.

Having procured four pups of the same litter, viz. A, B, C, and D, A was exposed to the action of this gas, contained under a glass vessel, for fifteen seconds, during which time he struggled very hard, respiration quick and short. He was now taken out, and immediately plunged under water, (without being permitted to respire atmospheric air) when he struggled very severely for four minutes and twenty seconds, after which he became feeble, and in five minutes and thirty seconds he ceased to move, and was taken out apparently dead, but on dissection motion was still perceptible in the heart, and the blood somewhat florid.

B was now exposed to its influence for the space of thirty seconds, after which he was immediately plunged under water. He continued to struggle very hard under the water for five minutes and thirty seconds, when he became weak, and considerably relaxed, he was taken out dead in six minutes and fifty-five seconds.

C and D were now plunged under water of the same temperature, in a natural state, and were confined below its surface. C was taken out dead in two minutes and fifty seconds, and D in three minutes and ten seconds; and, on dissection, the irritability of the heart was barely perceptible, and the blood completely disoxygenated.

Here the striking effect of this gas on the animal body, with that produced by oxygen, merits, in an eminent degree, the investigation of the philosopher. No satisfactory explanation has yet been given of this singular and interesting phenomenon. I shall not offer a conjecture on the subject. The fact is so that it increases action in the heart and animal fibre, producing a change in the arterial and venous blood, similar to that induced by oxygen gas.

Its modus operandi on the animal body, has been sup-

posed by a late celebrated author*, to be sedative, for, after relating an experiment made upon himself, by respiring this gas, proceeds thus " that hydrocarbonate acts as a sedative, i. e. that it produces diminution of vital action, and debility, without previously exciting it." This conclusion is not sanctioned by the result of the preceding experiments, where we find a very strong action is excited in the heart and arteries for the first sixty or eighty seconds, after the animals have been exposed to its influnce. We cannot doubt the accuracy of Mr. Davy's experiment, but the incorrectness of his conclusion is obvious.

From the result of the preceding experiments on *suspended life*, from drowning, hanging, and the action of unrespirable air, we infer the proximate cause of death to depend upon a disoxygenation of the blood and muscular fibre, in consequence of which a suspension of circulation takes place.

Whether the heart and animal fibre, derives its irritability from oxygen, through the medium of oxygenated arterial blood, as some modern medical philosophers have supposed, by reasoning from the result of experiment?—or

Whether it constitutes a powerful congenial or specific stimulus to the heart and muscular fibre, essential to their excitement, and therefore to animation? are questions that demand much and serious reflection, to enable the philosopher and enquirer after truth, to solve satisfactorily. I will leave the candid reader to judge for himself, the shortness of time, together with the limits of an inaugural thesis (which have already been overleaped in this essay), will not permit me to bestow, on this interesting part of science, that attention which it merits, and which I shall be happy to give at a future time.

The former hypothesis has been ingeniously defended by Dr. Girtanner, and is certainly founded on numerous and substantial facts, and, vice versa, there are many facts in the medical world that militate against it.

Thus then, we conclude, that the accumulation of black blood in the heart, the pulmonary artery and veins, and

* Humphrey Davy. Vide Chemical Researches, page 471.

other phenomena discovered to us by dissection, respecting the function of the lungs and the circulation of the blood, are nothing more than the effect of a disoxygenation of the blood and muscular fibre.

Hence we have demonstrated to us, in a convincing manner, the unbounded utility of the immediate application of this gas* (which may be justly called the magnum dei donum) in our attempts to remove a suspension of vital action from such unfortunate accidents.

INDICATIONS OF A TEMPORARY EXHAUSTION OF THE CAPACITY FOR LIFE WHICH MAY AGAIN BE ROUZED INTO ACTION BY THE APPLICATION OF POWERFUL STIMULI.

1. A degree of heat not much below the natural standard.

2. Feeble contraction and dilatations of the heart, felt externally.

3. A degree of tremor in the external muscles about the mouth, temples, abdomen, &c.

4. A contraction of the muscles in different parts of the body, on the application of common stimuli.

5. An alternate contraction and dilation of the pupils of the eye on the application of a strong light†.

* Oxygen gas. It can be obtained in very large quantities from several substances at a very reasonable rate. From one pound of the oxide of manganese, exposed in an earthen retort to a white heat, we procure at the trifling expense of one dollar, apparatus and every thing included ten gallons; would it not be a grand object to the humane societies, to keep always forty or fifty gallons of this air (which can readily be done by corking it up in tight bottles, or very close bags) to have recourse to on cases of emergency, where the loss of a few minutes in the restorative art is so frequently attended with such fatal consequences.

† I think it proper to observe, in this place, that the irritability of the iris, in every animal that I have killed, appears to be a very good external sign of the existence of the capacity for life. Having paid much attention to this circumstance in every animal I have experimented on for this dissertation. It seems to be more influenced by an equal degree of this principle with the heart, than any other external part, and retains it the longest. In all my dissections of animals, which I have made use of in this work, both of those submersed in water and those in the noxious gases, where I found the irritability of the iris weak and almost exhausted, I also found that of the heart very feeble, and *vice versa*; but I must confess, that these signs are liable to cause error, and ought never to be depended upon.

6. The smallest degree of remaining susceptibility is indicated, by removing the skin, fat, and cellular membrane, and applying to the muscular fibre the stimulus of the galvanic influence, when if the parts are not totally exhausted of irritability, some degree of motion will be excited.

INDICATIONS OF DEATH, OR A TOTAL EXHAUSTION OF THE CAPACITY FOR LIFE.*

1. A degree of heat, considerably below the temperature compatible with life.†

2. Rigidity of the body and limbs, which become inflexible.

3. A change of colour in the face, limbs, &c. from a healthy red to a leaden blue.

4. Great relaxation of the lower jaw, with considerable flacidity of the tongue, which hangs over the corner of the mouth.

5. Livid spots, attended with a cadaverous odour.

6. The eyes somewhat protruded, and the transparent cornea more glossy than natural, attended with dilated

* The relaxation of the sphincter anii, related by authors as a certain indication of death, is perfectly fallacious; and, from the result of my experiments, I may assert casual. In many of the animals, this relaxation of the part appeared to a great degree, before the external signs of life had disappeared; and, on the contrary, there were many instances, in which it did not occur at all. In several animals, in whom it appeared after submersion, and who shewed no external signs of life, on dissection, both sides of the heart continued in motion for some time; in two instances, for fifty minutes, and that not inconsiderable. In fact, the irritability of both sides of the heart, I have uniformly observed to continue for a length of time; in one case, for upwards of five hours, after that of the external muscular flesh, and the intestinal canal, had ceased entirely, and could not be made to contract by the galvanic influence.

† This does not take place immediately after submersion: as we find the temperature of the blood contained in the heart not to have been diminished, and as heat and irritability are not co-equal, it appears to be a very irrational criterion.

pupils, in which no contraction can be observed, on applying the most vivid light.

7. A morbid insensibility to the impression of stimulus.

8. A very certain sign of the extinction of life is a cessation of irritability in the muscular fibre, producing no contraction on the application of the stimulus of the galvanic influence*: but even this criterion is not infallible, for irritability may be totally exhausted in the external muscle and may still exist in the heart†, which retains its capacity for life the longest of any part of the animal body. Hence the uncertainty of external signs, to discriminate between life and death.

The books of authors on this subject, are replete with criteria to judge of the existence or non-existence of the irritable principle. It is not necessary, in this place, to take a separate view of the propriety or impropriety of adopting any of these ambiguous signs, when we have the accomplishment of so great an end in view, as that of restoring suspended life! Our exertions should never be influenced by any of them, but continued with ardour and unremitted attention, for a length of time. It would be more happy for our unfortunate patients, and a source of greater satisfaction to ourselves, were they expunged altogether. They are all fallacious, to a certain degree, and ought never to have the smallest influence on the propriety or impropriety of persevering in our attempts to revive the latent spark; for it is an unfortunate fact, that, in consequence of an ignorant confidence placed in them, persons, who might have been restored to life, to their friends, and to society, have been consigned to the grave.

This is an important subject, and one that has been anxiously investigated by philosophers, to discover a just criterion of judging with more certainty in these cases,

* To make use of this as a test, it is indispensibly necessary to remove the integuments, and then to operate upon the bare muscle.

† I mean, by the external muscular fibre, those which present themselves to our view, immediately on removing the skin, fat, and cellular membrane, in different parts of the body.

whether life is extinct, and our patient a mass of dead matter, or whether, by our perseverance, he may not be again recovered. The most indubitable sign is allowed to be a putrefaction of the body, or disorganization of the fibre. But as this criterion is not only extremely disagreeable, but must be attended, in some seasons of the year, with considerable danger, it is seldom applied. The application of the newly discovered phenomenon of animal electricity* appears to promise much on this head; for although irritability may exist in the heart, when not indicated by its application to the external muscular fibre, we may safely conclude it is so far exhausted, as not to be capable of again taking on the action of life.

EXPERIMENTS ON THE MODE OF CURE.

Having obtained a large quantity of pure oxygen gas, from the oxide of manganese, and erected the chain of tumblers of volta, to the number of one hundred and fifteen, and containing two hundred and thirty pieces of zinc and copper, from which I procured the galvanic influence very strong, I proceeded to apply them in recovering suspended life.

EXPERIMENT XLI.

A large dog was plunged under water, and confined below its surface for six minutes, after which he was taken out apparently dead, which was indicated by the common external signs. Sixty cubic inches of the gas was now thrown into his lungs, by means of a large gum-elastic syringe†, to which a flexible tube, with a common clyster pipe at its extremity, was appended. The gas was allowed

* The galvanic influence, which derives its name from its happy discoverer, professor Galvani, of the university of Bologna.

† For a description of the apparatus, and the various methods for inflating the lungs, &c. &c. I refer my readers to the ingenious works of Mr. Kite, Dr. Goodwyn, and others.

to remain in the lungs for twenty or thirty seconds, when it was again forced out by pressure. This artificial respiration was continued for five minutes, being repeated every thirty seconds; and during the intermission, the galvanic influence was applied to the region of the heart, which excited motion throughout every part of the body. The animal soon began to make feeble efforts to inspire, which, in a short time, he could effect with some ease. The artificial respiration was now discontinued, and the shocks from the chain of tumblers continued to be sent through the chest, until the heart had recovered its lost excitement.

EXPERIMENT XL.

Another dog, smaller in size, was treated in the same manner, when he was taken out in three minutes, with some remaining symptoms of life. The stimulus of the galvanic influence was applied to the region of the heart (having previously removed the hair), which was followed by a considerable degree of agitation throughout the whole body; this was continued for a short time, when the animal began to respire with much ease, and perfectly recovered in a few hours*. Two pups, of four weeks old, were successfully treated in the same manner.

EXPERIMENT XLI.

A half grown cat was submersed, taken out apparently dead in four minutes and fifty seconds. The lungs were immediately inflated with oxygen gas, which was forcibly thrown in by compressing the gum-elastic syringe, and an artificial respiration kept up for several minutes, when he was observed to make a feeble effort to inspire. The galvanic influence was now applied to

* In this experiment no artificial respiration was employed; conceiving it unnecessary from observing the animals to make some feeble inspirations, soon after being taken out of the water.

the region of the heart, which immediately excited a smart contraction; the animal began now to respire, which was still laborious, but soon became easy, and he recovered so as to escape in a few hours. In this animal, the pupil of the eye was observed to contract, though very feebly, on applying a vivid light.

EXPERIMENT XLII.

Two large spaniel pups were plunged under water, and confined there for seven minutes, at which time they were both taken out, apparently dead. No motion was apparent in the heart to the touch, but the muscular fibres of both of them contracted on applying the galvanic influence. The first was put up to the neck in the warm bath, at the temperature of ninety-eight of Fahrenheit's thermometer, which was gradually increased to one hundred and forty. In this medium he was allowed to remain for one hour, without its having produced any salutary effect; irritability was still perceptible in the fibres. Friction was now employed, and continued for a considerable time, aided by the injection of vitriolic æther per anum, but without the effect of restoring life. The lungs of the second were immediately inflated with fifty cubic inches of oxygen gas which was again forced out by pressure, and repeated at intervals of fifty seconds. This application was aided by shocks from the chain of tumblers, which were sent through the chest, with a view of applying it to both sides of the heart. This practice was persevered in for a considerable time, when the animal began to make feeble efforts to inspire. The shocks were now more frequently applied, and were increased in force, with the effect of exciting obvious motion in the heart. Artificial respiration was now discontinued, the animal respiring with more ease, and in four hours he recovered sufficiently to rise up. He was now placed on a bed of straw, and perfectly recovered in the course of three hours. Another dog was treated in a similar way, and with the same success.

EXPERIMENT XLIII.

A half grown bull-dog was suspended by the neck for six minutes; at this time he was cut down apparently dead. Irritability was still existing in the muscular fibres, which was produced by the stimulus of the galvanic influence. He was now laid upon the table, and his lungs inflated with sixty cubic inches of oxygen gas, keeping up an artificial respiration for several minutes, when the animal was observed to make a feeble attempt to inspire. The intercostal muscles were now laid bare, on both sides of the thorax, immediately opposite to the heart, after which a brass wire was curved in the shape of the letter V inverted, so that it should embrace both sides of the thorax at the same time, this was attached to a second conductor, communicating with the galvanic chain after which the shocks were sent immediately through the heart, with the effect of exciting considerable motion, and of increasing the process of respiration. This mode of cure was continued for some time, after which it was discontinued, and the wound closed up by ligature; the animal perfectly recovered in the course of the day.

EXPERIMENT XLIV.

Two pups, of six weeks old, were exposed to the action of carbonic acid gas for six minutes, at which time they were taken out apparently dead; their thighs and legs were pricked with a sharp instrument, but appeared to be insensible to the impression, the galvanic influence was applied to the bare muscle, when it began to contract instantly. Their lungs were now inflated with oxygen gas, and the stimulus of the galvanic influence applied in the manner related above. This mode of cure was continued for some time, when the animals began to make feeble efforts to inspire, which they could effect in a short time with considerable ease. This practice was now discontinued, and they both recovered rapidly. Several other experiments

of this tendency were repeated successfully, which I do not think proper to relate, the results being so similar, and the mode of cure the same; though it must be observed here, that this practice was not applied in every case with the same happy effect; it failed in one or two instances, notwithstanding it was applied, under the same circumstances, and continued with unremitted exertion for a considerable time.

Here, then, the indications of cure* are sufficiently obvious. The result of the above experiments point out to us the rationality of the practice adopted, and demonstrating at once the happiest effects resulting from its immediate application.

Far is it from my desire to expunge from the list of therapeutics, for suspended life, all of its articles. For although it contains a number of applications, which are not only useless, but prove highly injurious to the animal body in that state, it is by no means destitute of many important articles, but I would even have these viewed in the light of auxiliary applications to those applied in the practice adopted in this essay.

This truly important acquisition (the galvanic influence) to the list of applications in the restorative art† is entitled to our serious attention; for although we are induced to believe, from the many striking analogies existing between it and electricity, that it is only a modification of that power, we are convinced, at the same time, that as an application, in those cases, it possesses some peculiar and happy advantages over electricity. The difficulty and trouble of keeping an electrical machine in order: of working it in damp moist weather, the considerable diminution of its

* The transfusion of arterial failed in two instances, in the recovery of drowned animals. But I am informed that Dr. Gartley, who intended to write on this subject for his inaugural thesis last spring, made the same experiments with success. I think it merits much attention as an application in those cases.

† During the course of my experiments I had an opportunity of applying the galvanic influence succ5ssfully in two cases of suspended life, from severe cold, which occurred in two pups of two weeks old.

power in moist atmospheres, together with the uncertainty (unless in very skilful hands) of being able to proportion the shocks according to the capacity for life, on a perfect knowledge of which depends its successful application, are disadvantages long since experienced when it was applied under such circumstances. These are disadvantages not connected with the application of the galvanic influence. For in the first place, from observation, we find its power somewhat increased in the moist weather†, and not sensibly diminished in dry and clear weather from its natural standard, and, secondly, there is less trouble, and more economy in keeping it in perfect order, and, thirdly, the shocks can be proportioned to any capacity by only diminishing the number of tumblers. Nothing more is required to obtain it, than to fill up your tumblers or cups with salt and water, and to arrange them, either in a wooden frame made for the purpose, or upon the table, after which each vessel must contain a piece of zinc and copper, about as thick as a dollar, and an inch and a half square, these are to be connected together by brass wire. For the sum of forty dollars, in this way, we may procure one sufficiently powerful to kill small animals; as our object in these cases is economy, we should use those metals, which are the cheapest, and which have nearly the same power—zinc and silver—zinc and gold, &c. &c. have been used, but without much increasing the strength of the influence.

With this, then, illustrious professors! I close my inaugural essay, which, however imperfect, has been a work of much labour. It is unnecessary to add, that the time allotted to me for the completion of my task has been very short. The subject which I have chosen is, unquestionably, one of the first importance. However unworthy my efforts may be of your protection, from the criticisms of the illiberal, I have the satisfaction of assuring you and the public, I have made my experiments, and drawn my conclusions, unbiassed by any preconceived ideas on the subject.

† This accords with an observation made by Dr. Woodhouse, during his lectures on this subject.

In taking my leave of you, permit me to express my sincerest wishes, that you may enjoy, through the remainder of your lives, an uninterrupted scene of health and happiness. To all of you I am essentially indebted, not only for the invaluable instruction I have received from your lectures, but also for your polite and friendly attention.

THE END.